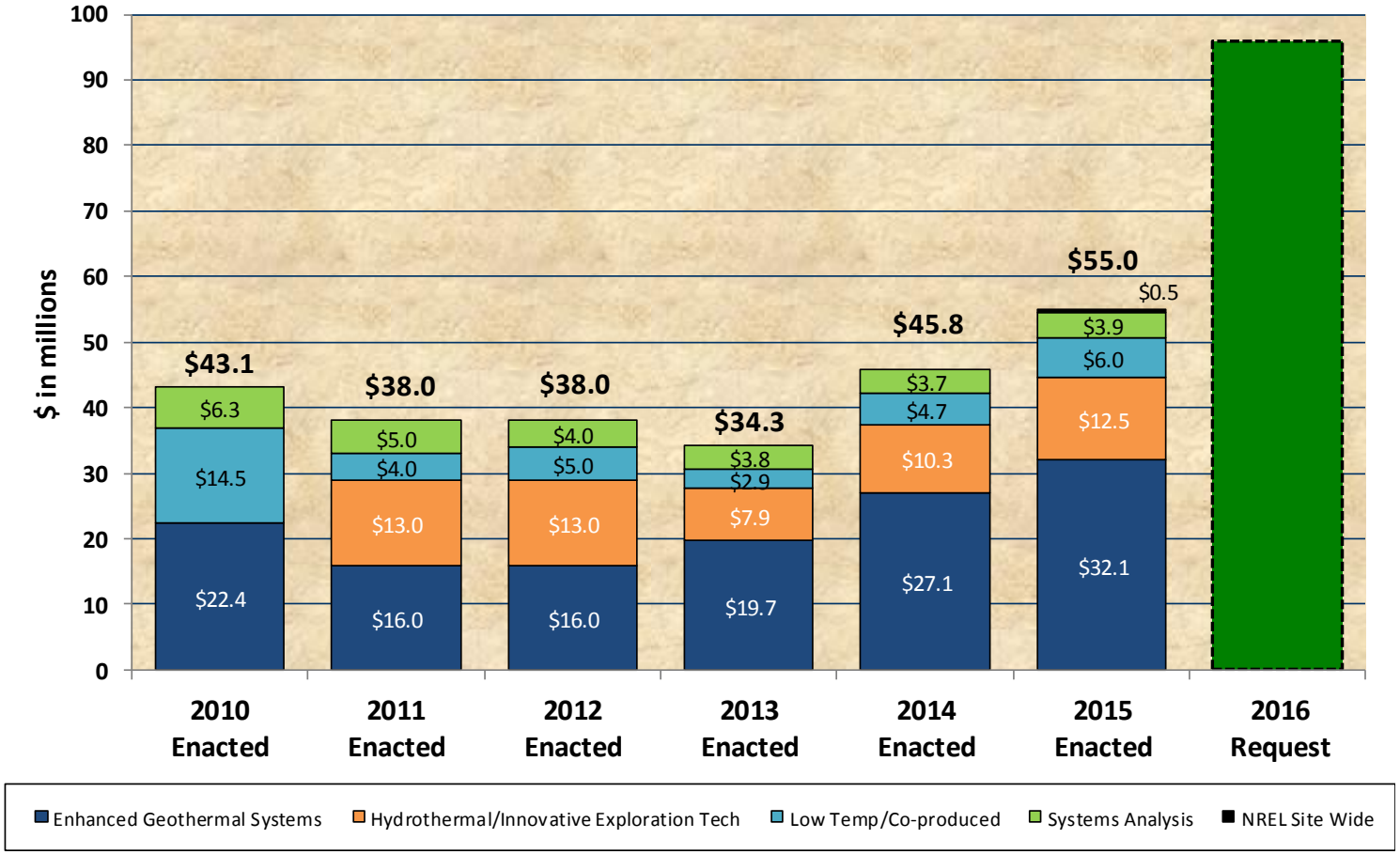
Stanford Geothermal Workshop

January 26-28, 2015

Jay Nathwani, Acting Director
Geothermal Technologies Office

DOE Budget, Geothermal Technologies Office, FY15



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Key Results on Funded Projects, FY14

SOURCE: Stillwater Hybrid, Enel Green Power Nofth America

FastCAP: GTO's $2.2 million investment has yielded **development and commercialization** of a cutting-edge power system for geothermal exploration in high vibration, extreme drilling environments. *courtesy FastCAP*

Oregon Institute of Technology: Commissioned **1.5 MW** of newly-installed geothermal power on campus, from a $1 million GTO award with $4 million match by Johnson Controls.

Pagosa Verde: GTO's $3.9 million **geothermal exploration project in Colorado** was matched by a $1.98 million state bond, with a bill signed by Colorado Governor Hickenlooper in May 2014.

Stillwater Hybrid Geothermal-Solar: **First-in-the-world hybrid geothermal-solar** facility in Fallon, Nevada produces 33 MW geothermal and 26 MW photo voltaic. An additional 2 MW Concentrated Solar Power project is under construction. With Idaho National Lab and National Renewable Energy Lab, GTO entered into agreement with Enel Green Power to explore potential and quantify the benefits of integrating geo energy with solar. *photo (left) courtesy of Enel Green Power North America*

Surprise Valley Electrification Corp:* a non-profit rural cooperative, plans to go online with a low-temperature, **3 MW geothermal power plant** in the near future, funded with $2 million in GTO Recovery Act funds, matched by a $3M Oregon Department of Energy Business tax credit. **Waste heat from the plant will be used for aquaculture, green house farming, and district heating.**

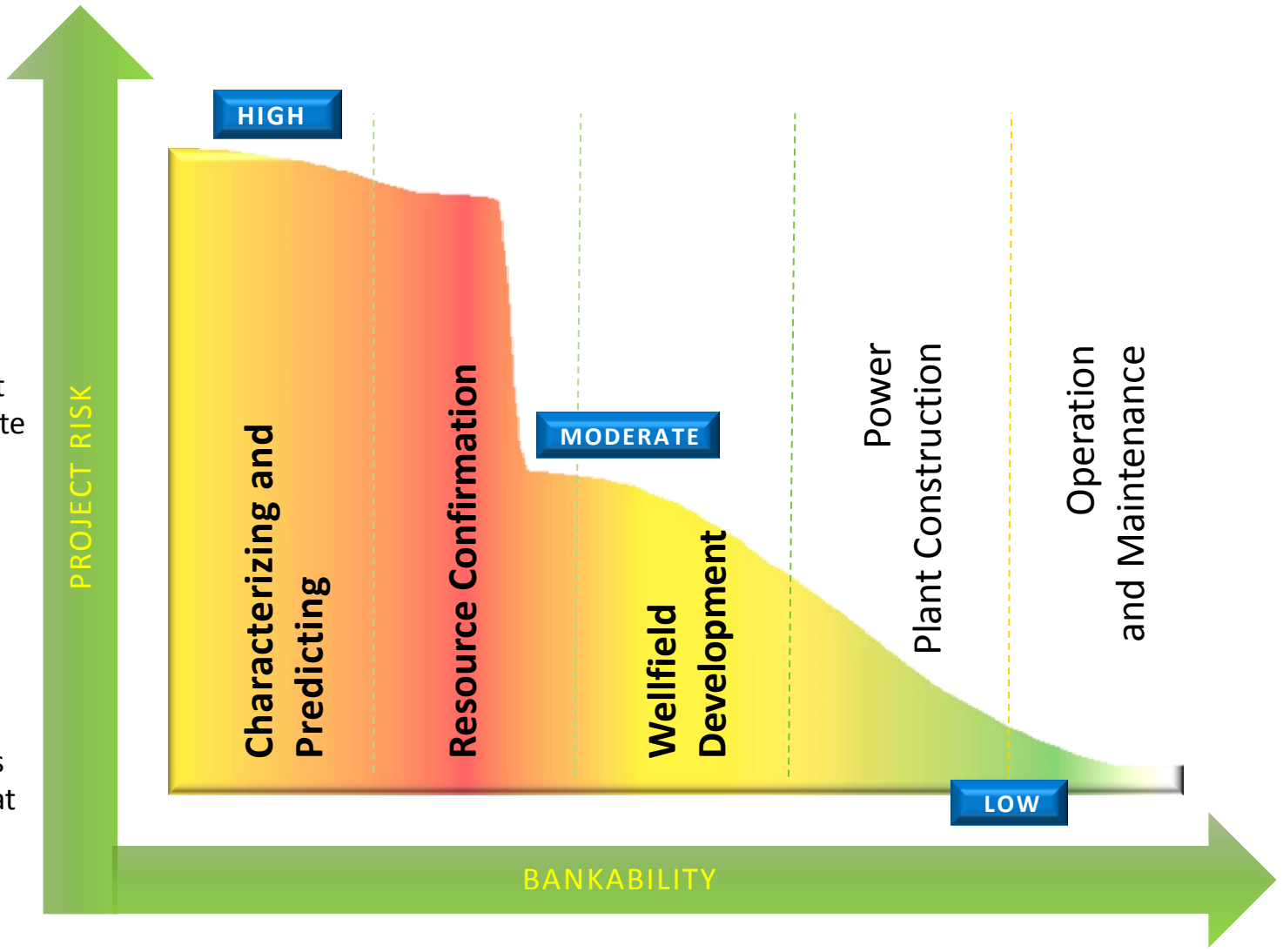
* Expected

Geothermal Lifecycle Costs and Risk: Stages to Deployment

The Energy Department addresses geothermal challenges at every stage of development

with a full complement of projects to accelerate the adoption of geothermal energy:

- Better targeted drilling
- Improved under-standing of the subsurface
- Innovate new tools and techniques that improve the value equation
- Lower upfront costs

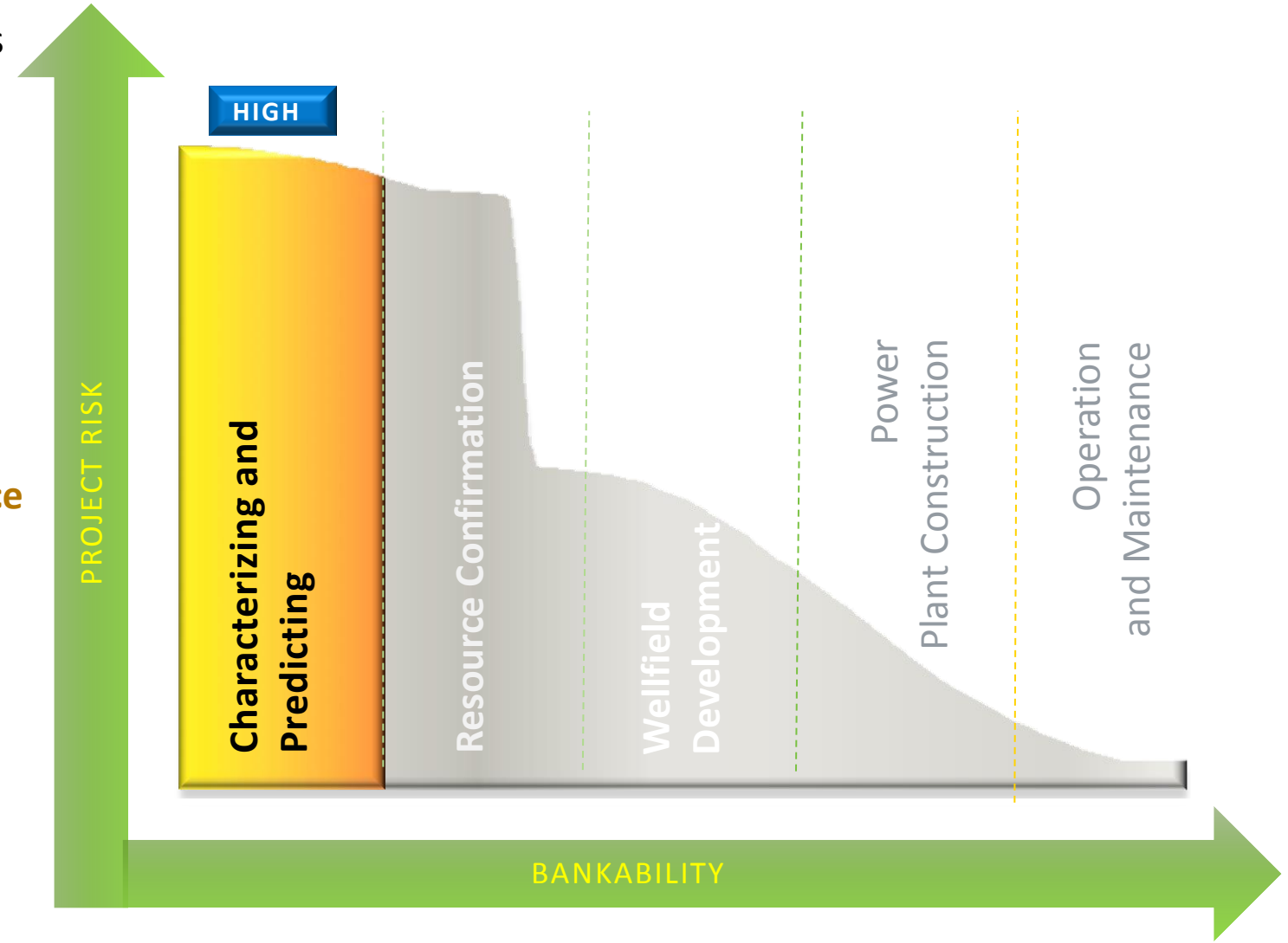


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Stage One: Characterize the Subsurface

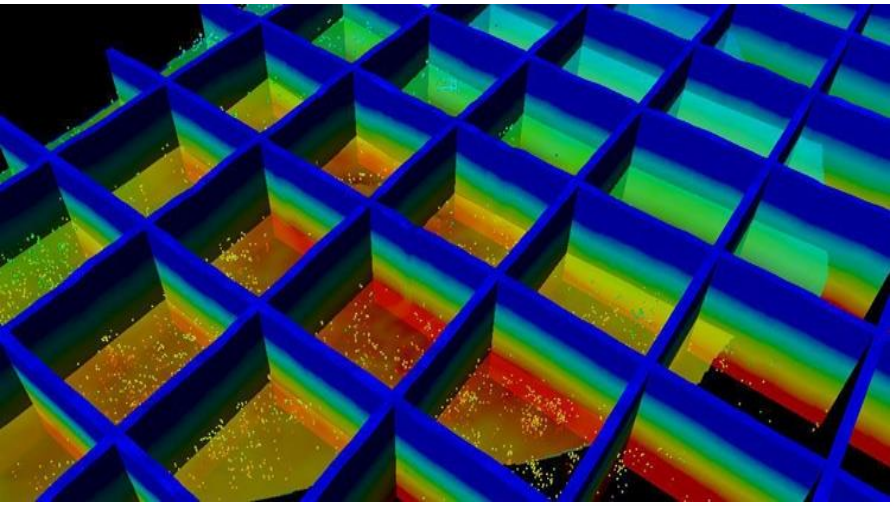
Mitigate the risks of geothermal exploration

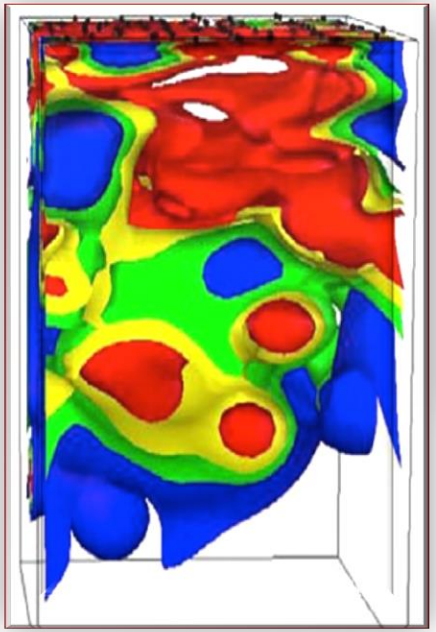
- National Geothermal Data System
- Play Fairway Analysis
- New Subsurface Signals
- Geochemical/ Geo-physical Tools
- Exploration Decision Tree



National Geothermal Data System

SOURCE: Schlumberger



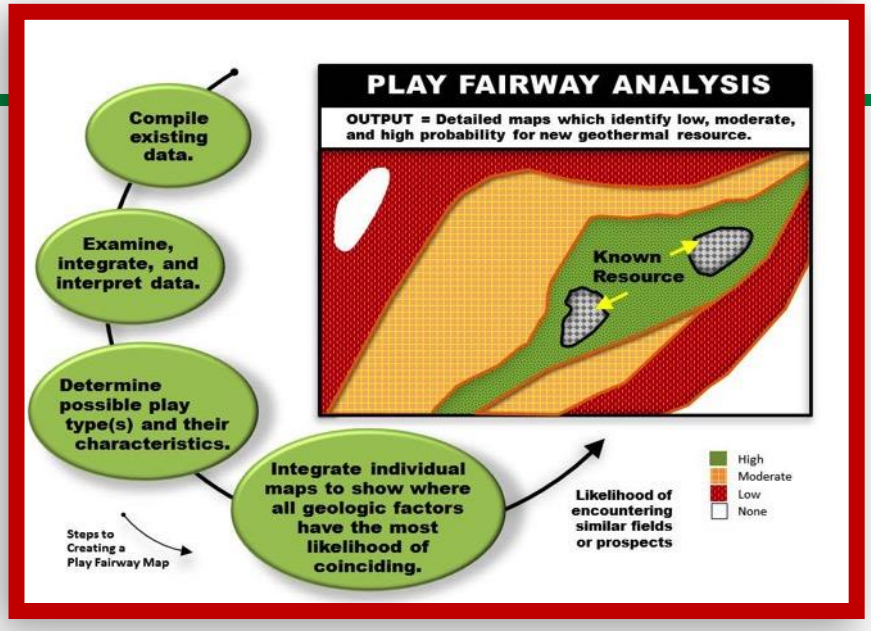


Deployed this best in class public tool for geothermal data collection and usability

- Addresses the lack of quantifiable data – a significant obstacle to geothermal development
- At deployment, nine million inter-operable GIS data points in 340 separate web feature and map services were available
- Supports the Energy Department's efforts to reduce cost and risks associated with widespread adoption of geothermal energy
- All DOE-funded research and demonstration data is represented in the DOE Geothermal Data Repository, a node on the NGDS
- **Award winning effort – 2014 Geothermal Energy Association Honors recognition**

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Play Fairway Analysis (PFA)

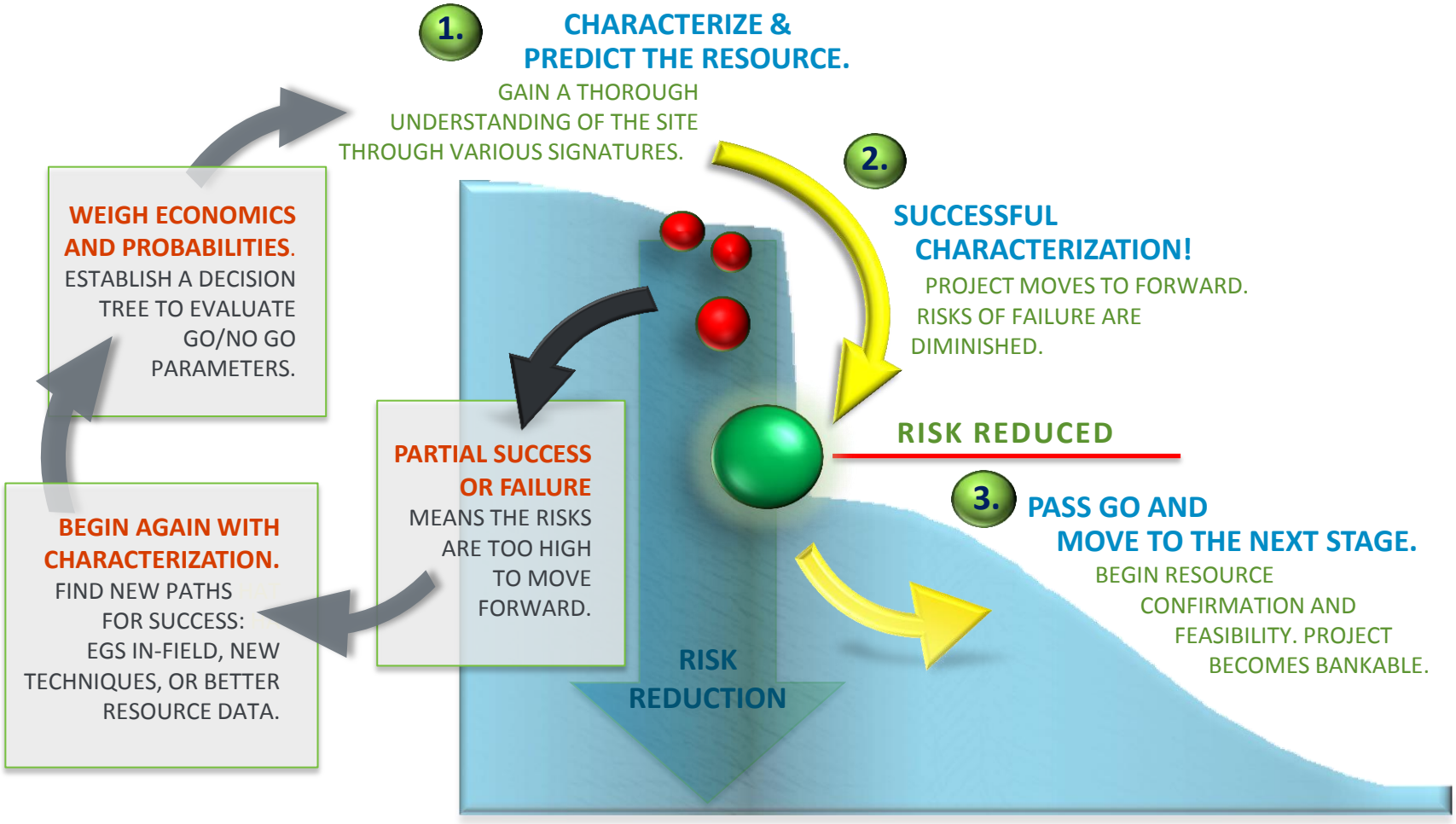


Before disturbing the ground, PFA reduces uncertainty and grades levels of prospectivity

- Identifies locations that have the highest probability of success
- Integrates known and conceptual data
- Determines potential plays
- Maps probabilities
- Focuses initially on unexplored and underexplored known geothermal regions
- Innovates analysis methods using public and private data

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Exploration Decision Tree



Projects can meet with success, or they can fail. Knowing how handle projects that remain at risk is vital to the economic production of geothermal energy.

The Exploration Funnel *(borrowed from Oil & Gas)*

100 Hot Spots

60 Plays

25 Prospects

11 Viable Projects

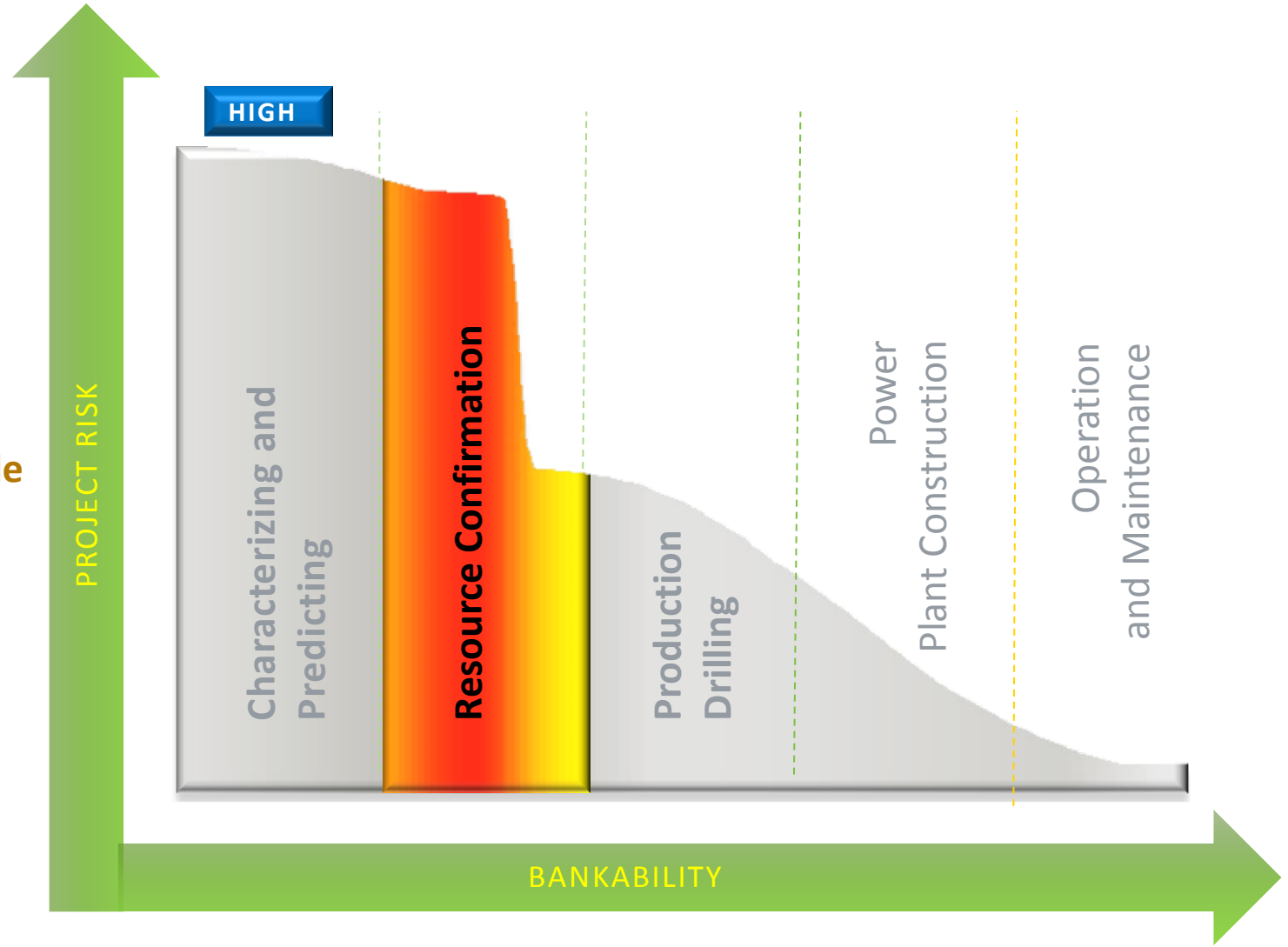
One Economic Project

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

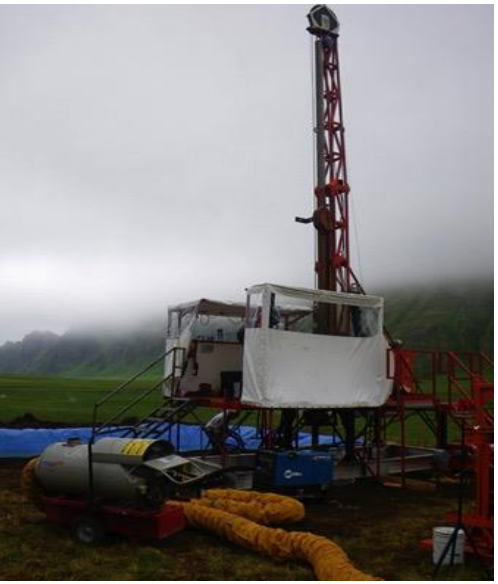
Stage Two: Resource Confirmation

Validate and confirm the resource with:

- **Innovative exploration drilling**
- **Microdrilling**
- **Novel downhole tools**
- **Flowtesting**



Innovative Exploration Drilling and Testing



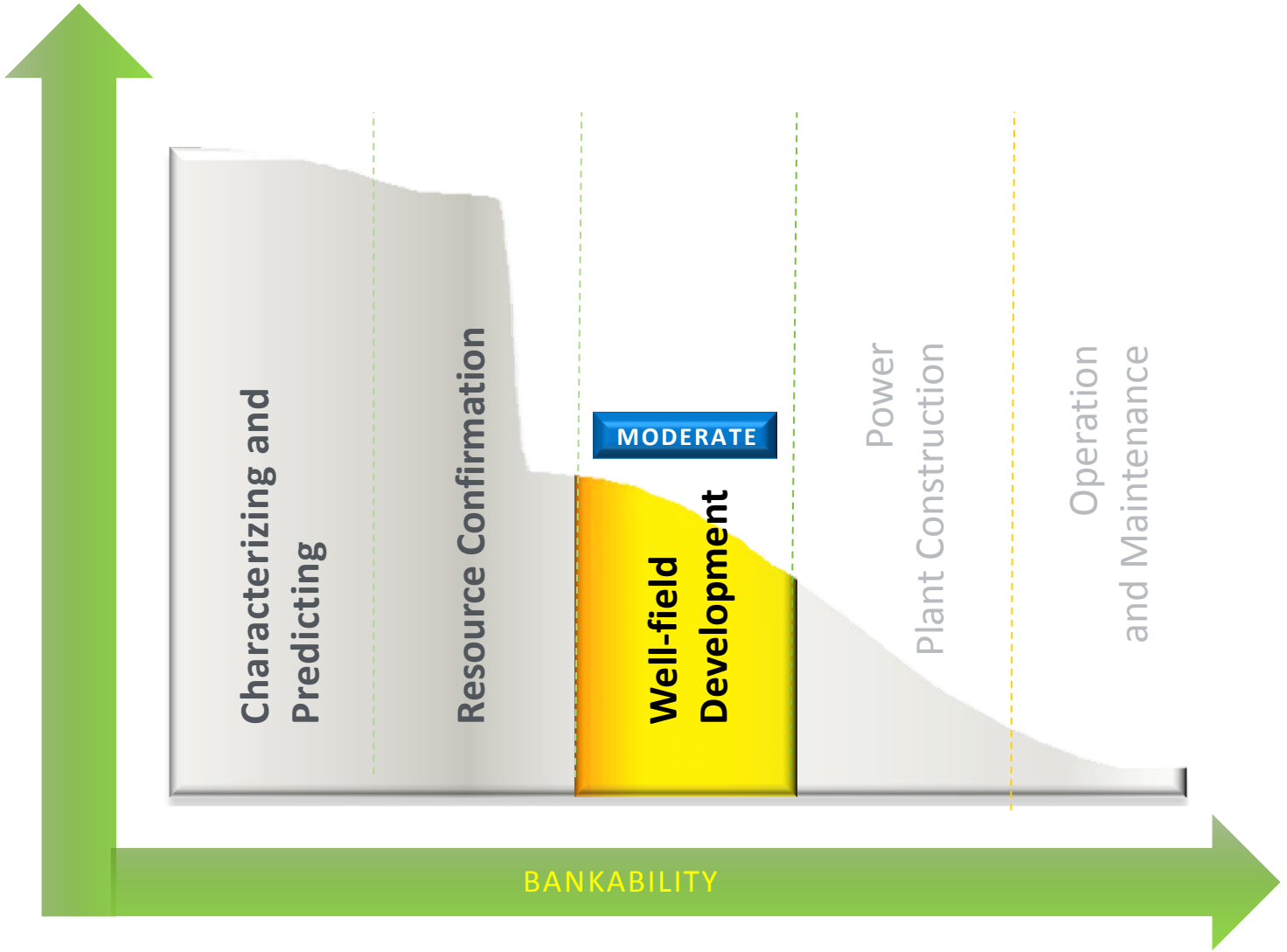
Validating prospective blind resources

- On-site active drilling projects
- Reduces risk through improvements in geothermal exploration
- USGS estimates 30 GW potential in blind hydrothermal systems in America
- Rigorous public-private collaboration
- Promotes economic viability of geothermal exploration technologies
- Identifies potential surface signals that can reveal deeper, hidden systems
- Play Fairway Validation Initiative

Stage Three: Wellfield Development

Reservoir engineering & optimization

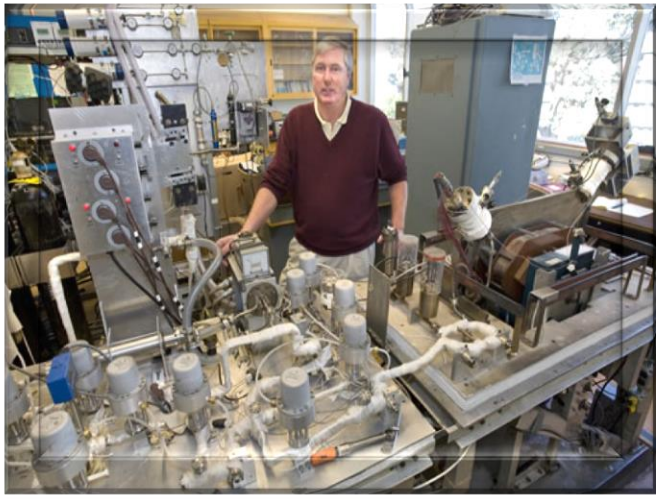
- EGS R&D
- FORGE Laboratory
- EGS



EGS R&D Projects

Laboratory research will improve methods for sustaining engineered reservoirs over time. The EGS R&D funding opportunity:

- **Uses novel techniques** — isotope studies, innovative rock mechanics experiments, integrated with geophysical methods, for instance — to increase the precision and accuracy of measuring critical underground reservoir properties over time.
- Focuses on laboratory feasibility studies to characterize critical EGS reservoir parameters — such as fracture length and aperture and fluid flow pathways — to **precisely engineer reservoirs**.
- Ultimately yields integrated characterization methods and **prototypes ready to be validated in the field.**

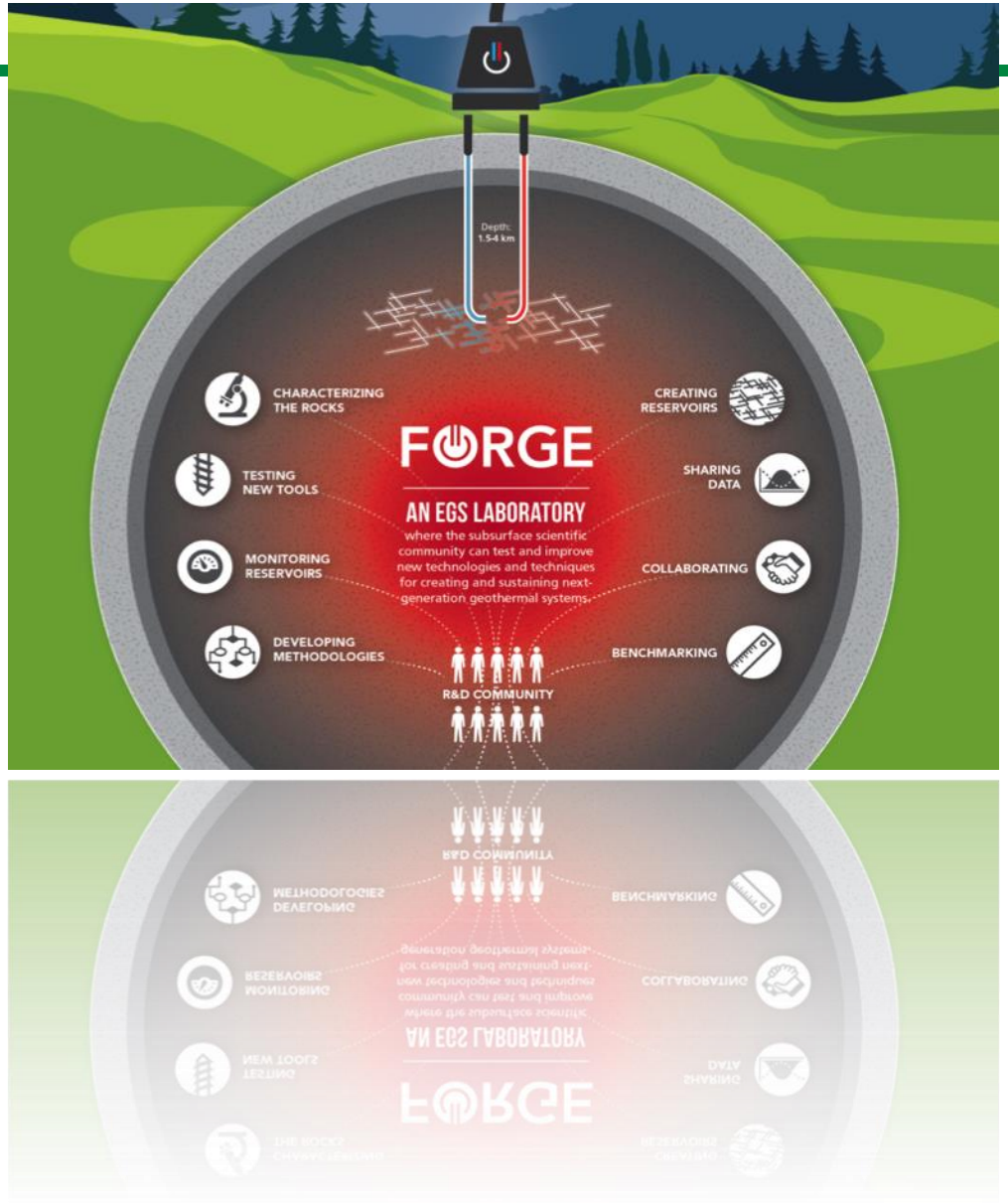


SOURCE: Lawrence Berkeley National Laboratory

FORGE Initiative

Undertaking transformative science to carve a commercial pathway for EGS

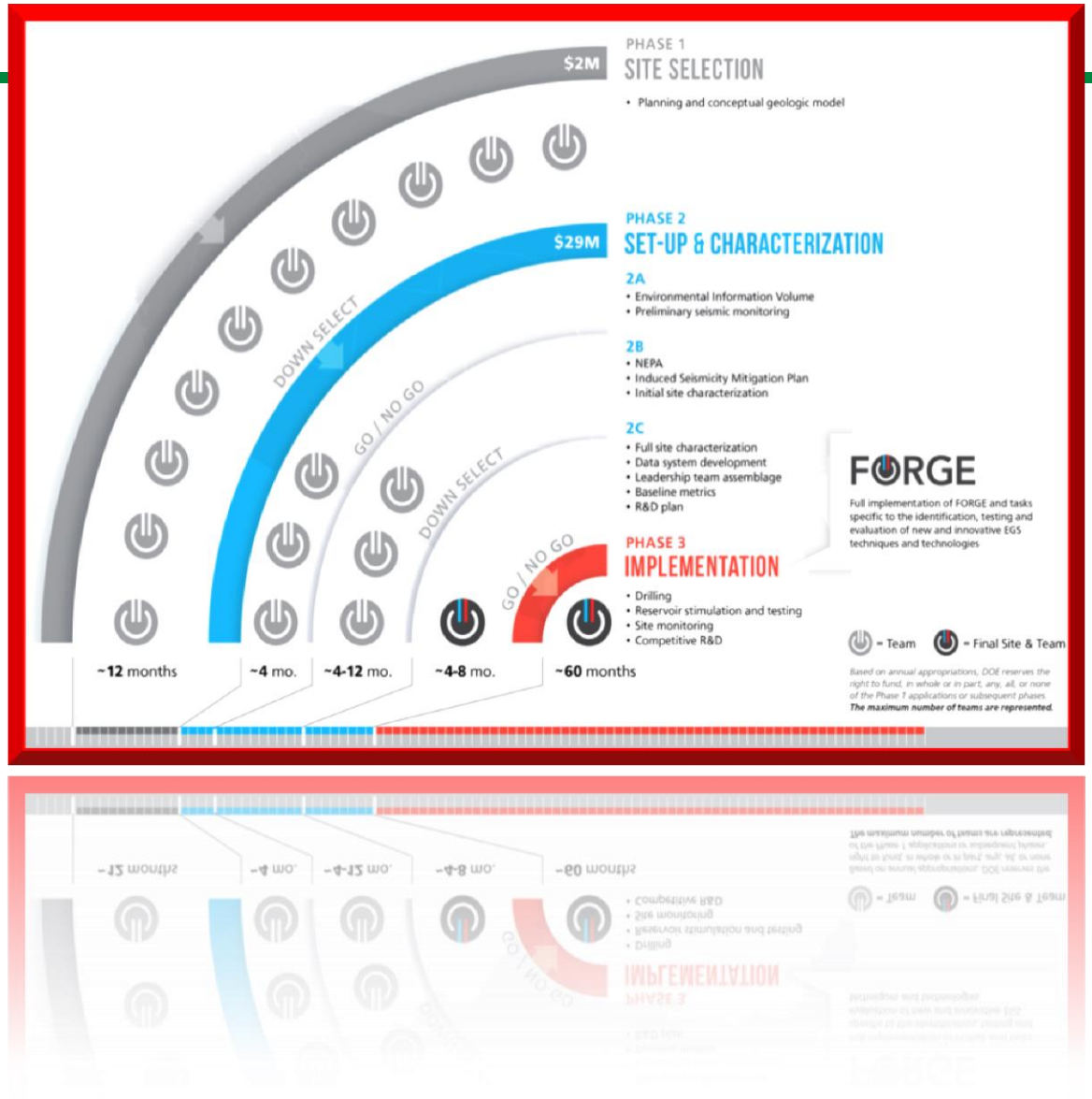
- Works collaboratively across national labs, academia, and industry
- To resolve some of the greatest hurdles to economic production of EGS geothermal energy



FORGE Initiative

Following a phased approach for fully implemented and characterized site selection

- $31 million solicitation in a phased approach
- Down-select to final site selection for the subsurface laboratory



Selections anticipated by March 2015

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EGS Demonstrations

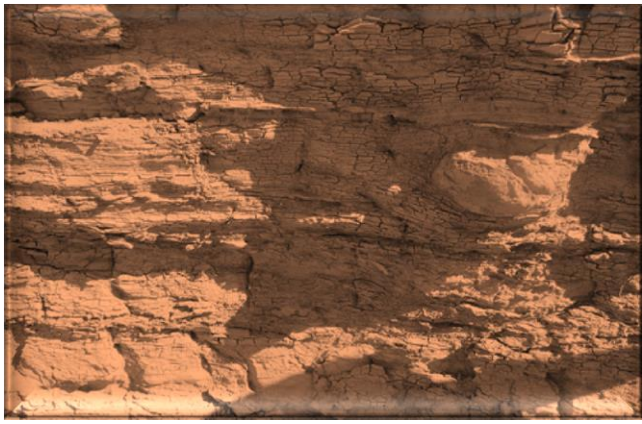
The Energy Department has valuable EGS demonstration projects in our portfolio.

AltaRock EGS demonstration project

- $21.4 million DOE Recovery Act investment
- Currently only project in our EGS portfolio located in a greenfield setting
- September 2014 – Stimulation was repeated after installing new casing
- EGS-6, 1st, 10:45am

Raft River EGS demonstration project in Idaho

- April 2014 – 10°C water at 3000-4000 lpm was injected – for hydraulic stimulation
- As of Jan 2015 over 666 million liters (176 million gallons)
- EGS-1 @10:45am

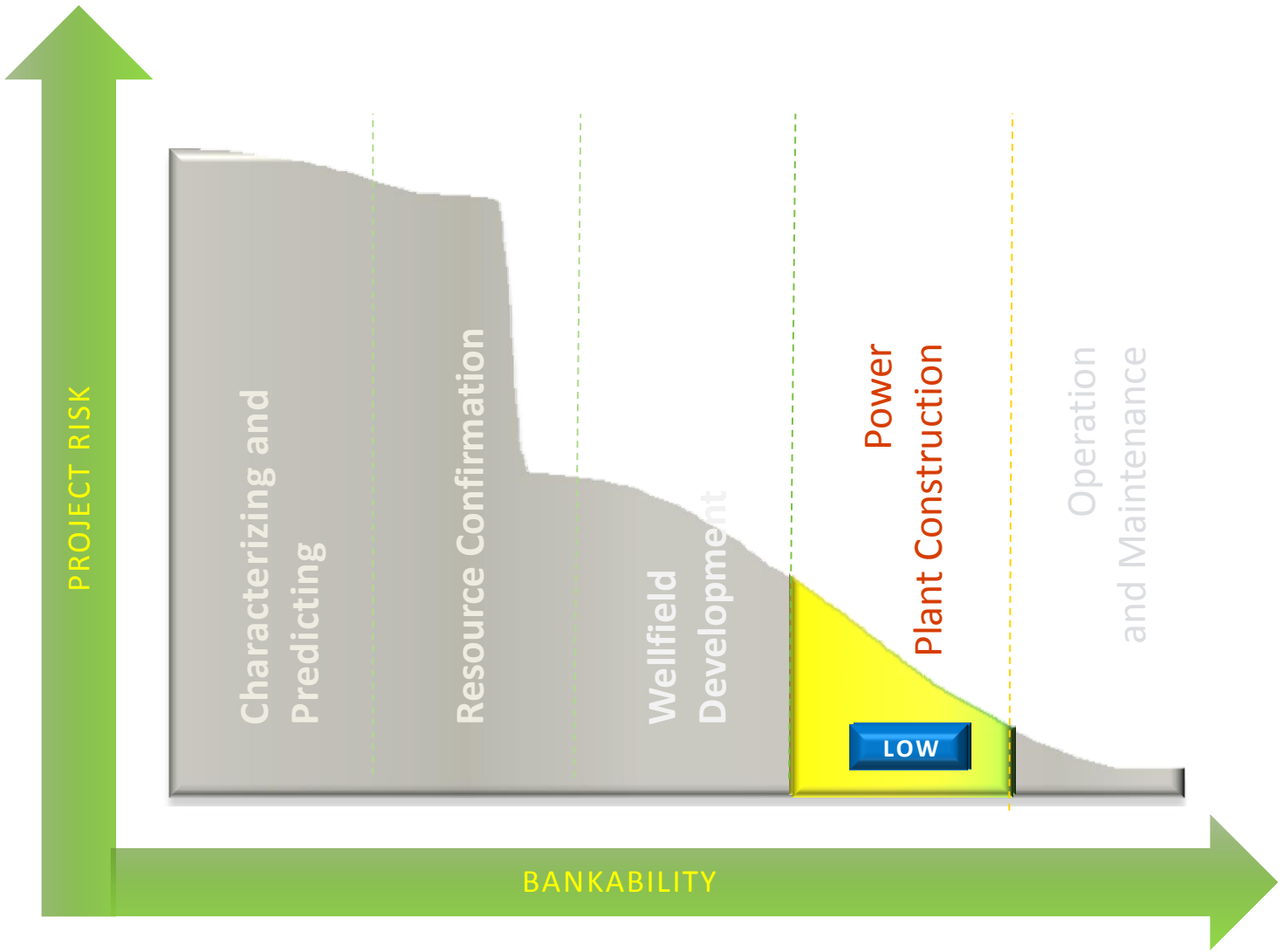


SOURCE: C. Pike, Alaska Center for Energy and Power

Stage Four: Power Plant Construction

Enhancing efficiencies

- Hybrid Power Systems
- Advanced heat transfer cycles
- Low-temperature applications
- Direct use & cascaded use

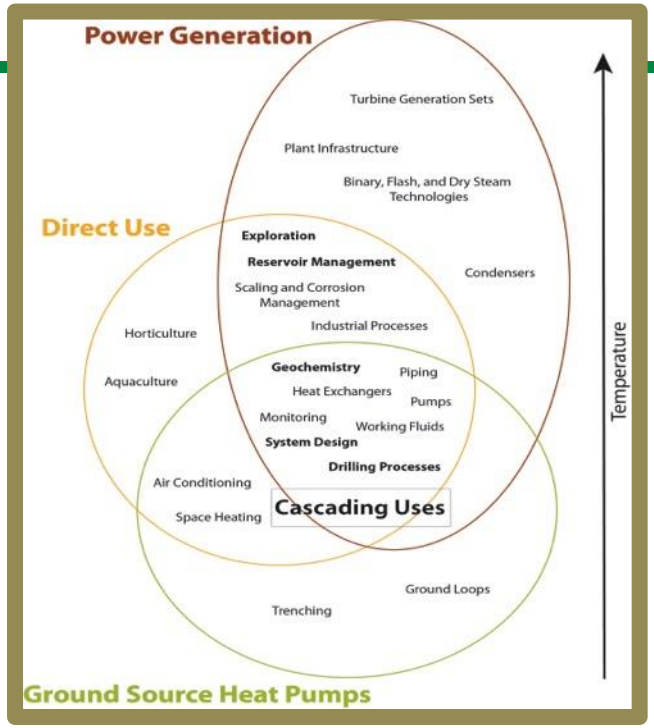


Direct Use and Hybrid Systems


SOURCE: Laura Garchar

Thermal energy applied directly for heating/ cooling, buildings, greenhouses, aquaculture, pools and spas

- Moderate temperatures between 100 – 300°F
- Wells hundreds to thousands of feet deep



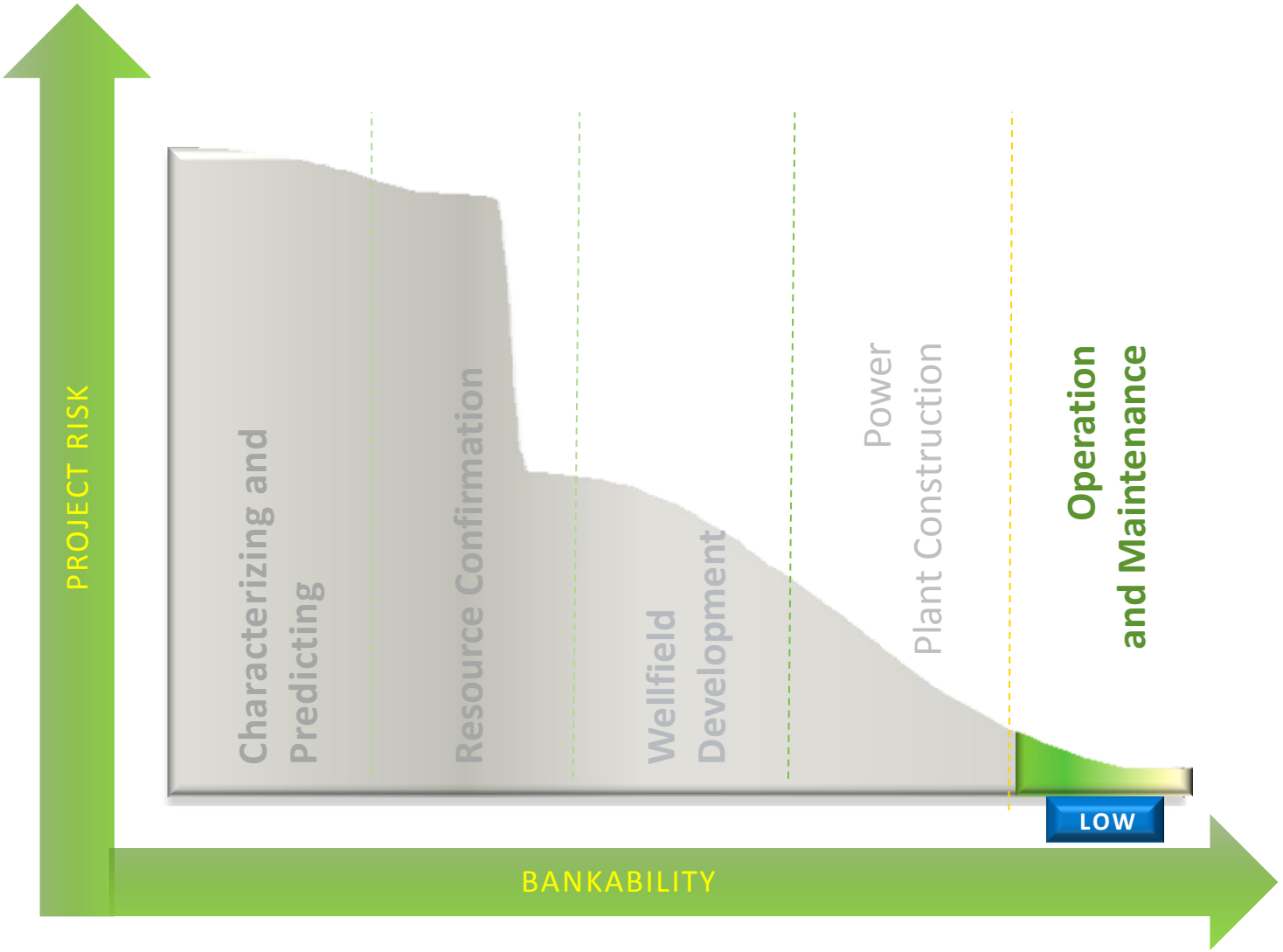
GTO is investing in innovative technologies to secure balanced renewable energy through hybrid systems

Stillwater geothermal plant, with a total net installed capacity of 33 MWe, will be integrated with a 17 MW solar thermal facility. This is the first hybrid plant in the world able to combine the continuous generating capacity of binary-cycle, medium-enthalpy geothermal power with solar thermal technology.

Stage Five: Operation & Maintenance and Additive Value

Increasing value propositions to make geothermal more economical

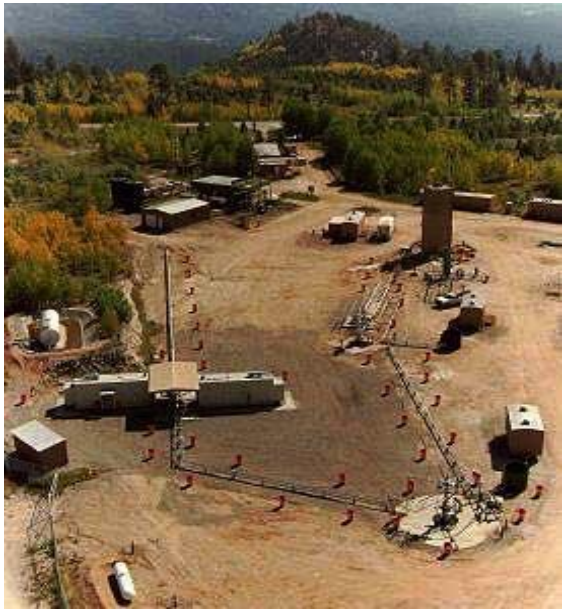
- Mineral recovery
- Innovative O&M Tools, Sensors, Methodology



Mineral Recovery

To economically extract rare earths and other strategic materials from geothermal brines increases the value proposition of geothermal energy production.

- Feasibility studies that include fully developed business plans laying out the **technical** feasibility and **economic** viability of mineral extraction technology(s) combined with geothermal power production at a new or existing geothermal resource.
- Assessments of the current rare earth and near-critical metal resource base, with potential extraction volumes/rates including coupled techno-economic analysis.
- Geochemical modeling and leaching experiments to optimize the composition of down-hole fluids and identify additives that selectively leach high value strategic elements.



GTO Vision Study

New Prospecting Opportunities

Play Fairway Analysis GO/NO GO decision

Announcing play fairway drilling validation opportunity

Advancing Innovative Geothermal Tools & Techniques

Build upon R&D and demonstration project successes

Initiate Phase I, Frontier Observatory for Research in Geothermal Energy (FORGE)

Geothermal Vision Study

Geothermal continuum

Value proposition and its Impact on the President's Climate Action Plan

Additive Value

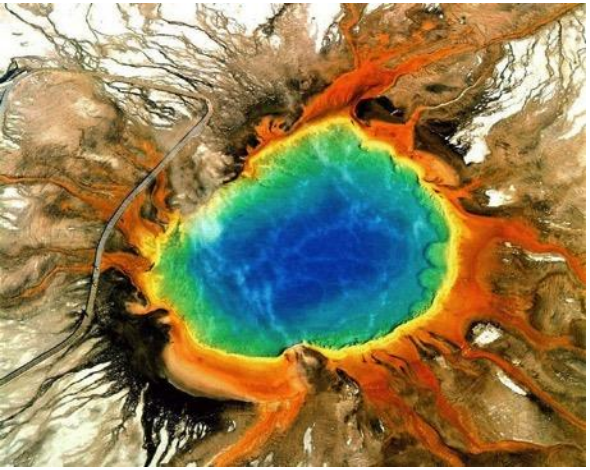
Low-Temperature Mineral Recovery

Hybrid systems

Subsurface Engineering Crosscut (SubTER)

Intra- and inter-agency effort to address common subsurface challenges and better leverage DOE R&D

GTO Vision Study



By 2016, DOE seeks to develop credible analysis jointly with the GEA/GRC community that:

I. Articulates clear ***GTO investment strategies*** across different sectors and has a cohesive plan to attain the goals;

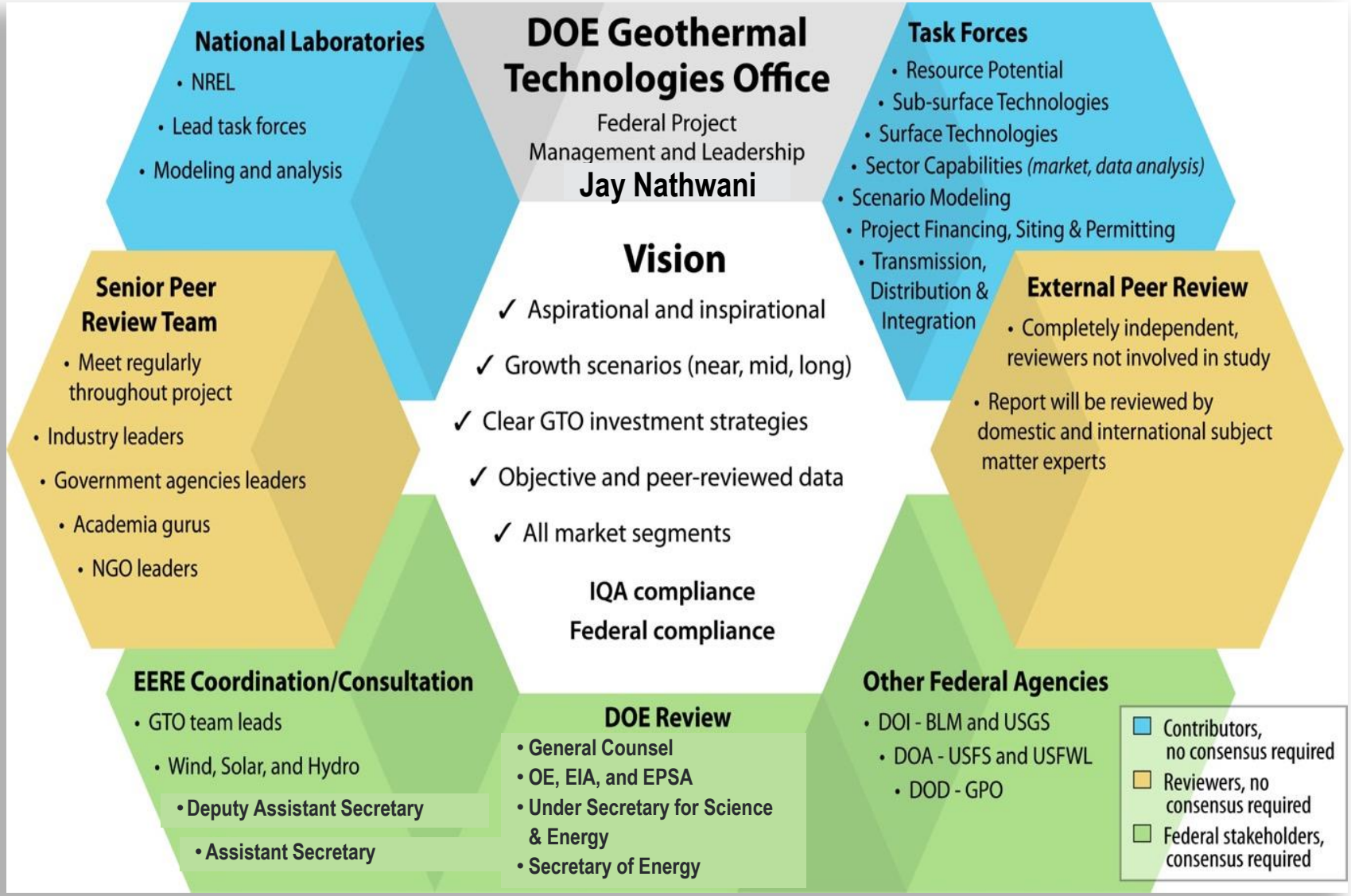
II. Discusses ***geothermal growth scenarios*** for 2020, 2030 and 2050 backed by robust data, modeling and analysis;

III. Addresses *all market segments* existing and potential hydrothermal, electrical and non-electrical usages, new EGS sector, and other value streams; and is

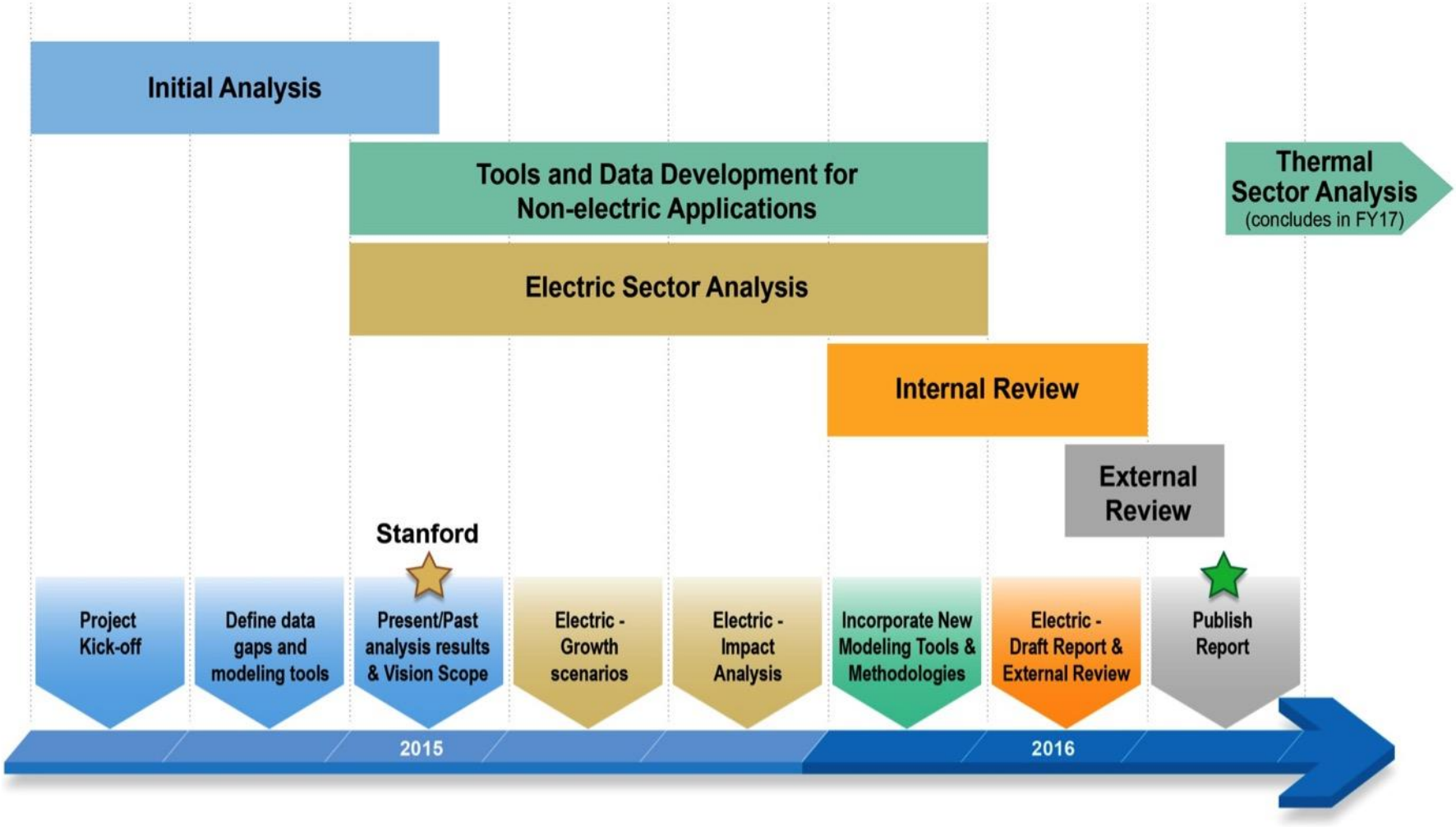
IV. Supported by *objective and* ***peer-reviewed industry data*** and *available to decision-makers*

V. Is ***aspirational*** and ***inspirational***

GTO Vision Study

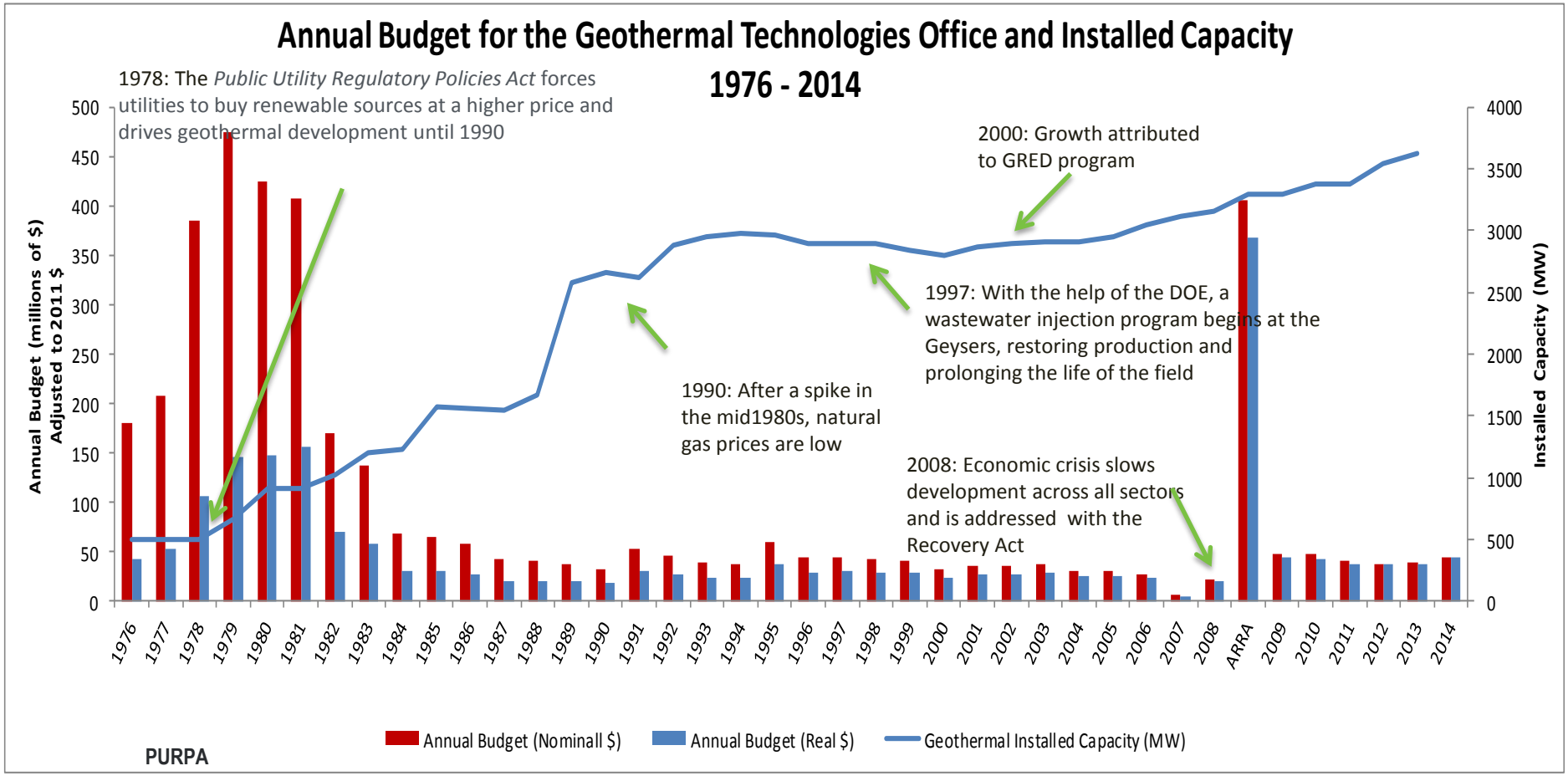


GTO Vision Study



1976-2014

The Geothermal Technologies Program annual budget peaked in the late 1970s, helping to drive an increase in installed capacity that lasted about ten years.



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy